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Analyses of occurrence data of protected insect species collected by citizens in Italy

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Abstract

Citizen science, the engagement of people in a research project, has grown rapidly in recent years, also for mapping of species of conservation interest. The Life Project "Monitoring Insects with Public Participation" (MIPP) actively promoted collaboration amongst scientists, public administrations and citizens in the collection of occurrence data of nine insect species listed in the Habitats Directive: *Lucanus cervus*, *Osmoderma eremita*, *Cerambyx cerdo*, *Rosalia alpina*, *Morimus asper/funereus*, *Lopinga achine*, *Parnassius apollo*, *Zerynthia cassandra/polyxena* and *Saga pedo*. These species were selected because they share two main characteristics: (i) they are listed in Annexes II and IV of the Habitats Directive and (ii) they are large and relatively easy to identify. From 2014 to 2016, many different strategies were applied to contact and engage the public and approximately 14,000 citizens were reached directly. Additionally, printed and

online material informed the public about this project. Citizens could transmit data on the target species, accompanied by a photograph, via the web-site of the project or through a dedicated application (app) for smartphones and tablets. All records were validated by experts based on the photographs sent by citizens. A total number of 2,308 records were transmitted and 1,691 (73.2%) of these were confirmed. Most of the reports were submitted via the website, although the submission via the app increased over time. The species most commonly recorded was *L. cervus*, followed by *M. asper/funereus* and *R. alpina*. Data collected by citizen scientists allowed a detailed analysis to be made on altitudinal distribution and phenology of the species and the results obtained were compared with literature data on altitudinal distribution and phenology. For example, for *L. cervus*, 67% of the records collected were from the altitudinal range 0–400 m a.s.l. Interestingly, the data showed that the phenology of this species changed with altitude.

Keywords
Citizen Science, Habitats Directive, Phenology, Altitudinal distribution

Introduction

Citizen Science (hereafter CS), the engagement of people in order that "scientists and the public work together to investigate and address emergent environmental issues" (Kobori et al. 2016), refers to a wide range of activities that involve lay people at some point in the research process, from research design, to data collection (Bonney et al. 2009), data processing (Raddick et al. 2010) and education (Wiggins and Crowston 2011). CS has grown rapidly in recent years and currently more than 500 English-language CS projects on biodiversity research are known (Kobori et al. 2016) and a number of databases exist (e.g. CitizenScience.org, SciStarter.com). Publication of data from CS projects in peer-reviewed journals is also increasing (Theobald et al. 2015).

The CS approach has been applied for insect monitoring in a great number of projects with a wide range of geographical scales, for example:

- Urban: butterflies monitoring in the cities of Chicago, New York and Tokyo (Matteson et al. 2012, Washitani et al. 2013); Invasive Alien Bumblebee in Hokkaido (Kadoya et al. 2009).
- National: butterfly monitoring in Germany (http://www.science4you.org), Ireland (Donnelly et al. 2014) and Malaysia (Wilson et al. 2015); anglers monitoring initiative of UK (http://www.riverflies.org); UK Ladybird Survey (UKLS; http://www.ladybird-survey.org); insect monitoring in South Africa (Lovell et al. 2009); Swedish Species Observations System (http://www.artportalen.se).
- Continental: Monarch Larva Monitoring Project (http://monarchlab.org/mlmp); migration and trends of Monarch butterflies (Oberhauser and Prysby 2008, Howard and Davis 2009, Davis 2015); Fireflies (Firefly Watch USA), Lost Ladybug Project (LLP; http://lostladybug.org); Swiss pan-European study of the migratory behaviour of the Red Admiral butterfly (https://insectmigration.wordpress.com/red-admiral-migration/).

Moreover, CS has been used to assess the impact of climate change on butterflies and moths (Parmesan et al. 1999, Warren et al. 2001, Fox et al. 2014) and to study pollinators (http://greatpollinatorproject.org/, review in Kremen et al. 2011, Toomey and Domroese 2013) and the land-use preferences of flower visitors (Deguines et al. 2012, Fox et al. 2014).

The effort required from citizens for the insect monitoring varies from simple observations to the application of a standard monitoring protocol. Examples for CS standardised monitoring are the European Grassland Butterfly Indicator (van Swaay et al. 2008, 2013) and the bumble bee monitoring scheme of Ireland (Donnelly et al. 2014).

Despite the great number of projects aimed at insect monitoring, compared with the total number of species considered in such programmes, invertebrates have been under-sampled by CS and, within invertebrates, butterflies have been over-sampled and beetles have been under-sampled (Theobald et al. 2015).

In this context, the LIFE11 NAT/IT/000252 Project – Monitoring of Insects with Public Participation (MIPP) – promoted active collaboration amongst scientists, public administrations and citizens in the collection of occurrence data for nine target insect species listed in the Habitats Directive (Mason et al. 2015, Zapponi et al. 2017). The aims of the CS programme, developed during the project MIPP, were: (i) education - increasing public knowledge on the habitat, biology and threats of the target species, (ii) awareness - promoting environmental awareness and changes in attitudes and behaviour of the public and (iii) faunistic knowledge - mapping the current distribution of the species.

The CS MIPP programme can be classified as a "cross sectional surveying" (Tulloch et al. 2013), which means that volunteers are free to choose when and where to collect occurrence data. This "undirected approach" to data collection, may result in more rapid and efficient detection of species which is particularly important for a project with a defined duration and which focused on rare species, even if it is less consistent in data collection compared with a standardised protocol (Matteson et al. 2012). Moreover, MIPP is a "verified citizen science" programme (Gardiner et al. 2012), as validation of data is ensured by specialists. Data collected by citizens is an extremely valuable instrument for studies on ecology and distribution of insects (Widenfalk et al. 2014). For example, Zapponi et al. (2017) found that the dataset obtained in two years by citizens resulted in an increase in the distributional ranges of three beetle species, compared with a national inventory provided by experts.

The project used information and communication technology (ICT) to collect geo-referenced faunistic data while adding ecological data for the site observation was optional. Above all, applications for wireless devices (smartphones and tablets) can potentially turn anyone into a citizen scientist, enabling them to act as remote sensors for all sorts of data. These devices can collect data more efficiently and in an automated way while, at the same time, limiting human errors and incorporating many important data-gathering functions - such as capturing images, audio and text - into a single tool that can "stamp" the date, time and geographic coordinates associated with an observation (Teacher et al. 2013). The rise of the internet has seen a 'new

wave' of online CS projects, sometimes termed 'citizen cyberscience' and has greatly improved the ability to find participants and interact with them. Additionally, it has facilitated data collection by communities of local people who were traditionally not involved in scientific projects and has offered new ways to potentially influence how science and policy-making are carried out (Graham et al. 2011, Newman et al. 2012, Haklay 2013, Kobori et al. 2016). The project MIPP also used social media which can produce long-term benefits for the project itself and important outputs for conservation (Jue and Daniels 2015), for example, by recruiting volunteers for field activities, by advertising events or by inviting citizens who had posted pictures of the target species on social media and also by sending their records to the MIPP database. Additionally, they allowed symbolic rewards to be provided to participants to strengthen their loyalty to the project and consequently, to provide a larger quantity of data (Hochachka et al. 2012).

The target species

Osmoderma eremita (Scopoli, 1763) (Coleoptera, Scarabaeidae) is listed as a priority species in Annexes II and IV of the Habitats Directive, its typical habitat being the cavities of old broadleaf trees. The species is presented in detail (biology, ecology and monitoring methods) by Maurizi et al. (2017).

Lucanus cervus (Linnaeus, 1758) (Coleoptera, Lucanidae) is listed in Annex II of the Habitats Directive. Its larvae feed on dead wood from different broadleaved tree species, mainly oaks, in contact with the ground. Biology, ecology and monitoring methods of the stag beetle are presented in detail by Bardiani et al. (2017).

Cerambyx cerdo Linnaeus,1758 (Coleoptera, Cerambycidae) is listed in Annexes II and IV of the Habitats Directive. It typically lives in large, old trees (especially oaks) which are, at least partially, exposed to the sun. Redolfi De Zan et al. (2017) provided details on biology, ecology and monitoring methods for this species.

Rosalia alpina (Linnaeus, 1758) (Coleoptera, Cerambycidae) is listed as a priority species in Annexes II and IV of the Habitats Directive and larvae typically develop in wood of large *Fagus sylvatica* but sometimes also in other broadleafed tree species. Biology, ecology and monitoring methods of *R. alpina* are presented in detail by Campanaro et al. (2017).

Morimus funereus Mulsant, 1863 (Coleoptera, Cerambycidae) is listed in Annex II of the Habitats Directive. However, a recent genetic study (Solano et al. 2013) showed that all European and Turkish populations of the genus *Morimus* Brullé, 1832 should be referred to as *M. asper* (Sulzer, 1776) (a genetically and morphologically highly variable taxon) and *funereus* is considered a sub-species (Solano et al. 2013). The larval development takes place in recently cut wood, stumps and trunks of damaged trees. Biology, ecology and monitoring methods for this species are provided by Hardersen et al. (2017).

Lopinga achine (Scopoli, 1763) (Lepidoptera, Nymphalidae) is listed in Annex IV of the Habitats Directive. Its main habitats are forest clearings and forest margins and its larvae feed on *Brachypodium* grasses. In Italy, the species is confined to the Alps.

Parnassius apollo (Linnaeus, 1758) (Lepidoptera, Papilionidae) is listed in Annex IV of the Habitats Directive, mainly occurring in mountain areas on steep, sunny slopes with sparse vegetation and its larvae feed on *Sedum* ssp. and *Sempervivum*.

Zerynthia polyxena (Geyer, 1828) (Lepidoptera, Papilionidae) is listed in Annex IV of the Habitats Directive; however, recent studies have shown that, in central and southern Italy, an endemic sister species, *Z. cassandra* (Dapporto 2010, Zinetti et al. 2013) is present. The larvae of both species feed on the host-plant *Aristolochia* ssp. and are generally found in open habitats such as forest clearings and edges, slopes, open forests or meadows.

Saga pedo Pallas, 1771 (Orthoptera, Tettigonidae) is a parthenogenetic species listed in Annex IV of the Habitats Directive. It is a xerothermophylous species inhabiting dry meadows, pastures and shrubby hillsides. *S. pedo* feeds mainly on other grasshoppers.

Research Objectives

The objectives of this paper are two-fold: (i) to describe the different strategies adopted to engage people in the LIFE project MIPP and to analyse the results of participation by volunteers and (ii) to use the data transmitted to upgrade knowledge of the altitudinal distribution and the phenology of the target species by comparing these results with the most relevant literature.

Materials and methods

Volunteer engagement

Engaging citizen volunteers to monitor and manage natural resources, track species at risk and conserve protected areas is increasing, especially by non-governmental organisations. The contribution of volunteers to natural sciences is not new; in museums, there are hundreds of millions of plants and animals specimens which have been collected by volunteers. However, with CS, the engagement of volunteers is increasing and now makes it possible to carry out monitoring programmes which constitute a new challenge for science (Cathy et al. 2011, Bordogna et al. 2014). In the MIPP project, volunteers were asked to provide records, accompanied by photographs of the target species through a web-site or via the app "MIPP" for smartphones and tablets.

Different strategies were applied to engage the public from 2014 to 2016. The MIPP staff met citizens "face-to-face" during seminars, workshops and dissemination events in cities, in science museums and in nature reserves. Other means used to contact the public were talks and posters at conferences and guided tours. Additionally,

a specific education programme for schools was carried out in several Italian regions (see Carpaneto et al. 2017, for details). A total of 403 activities were carried out during 2014–2016, with approximately 14,000 citizens reached (Table 1). These activities involved pupils from primary to high school, university students, professors and technical personnel from nature reserves. Media-related communication activities included the website of the project, social networks (Facebook, YouTube, Twitter), two documentaries transmitted on national TV, 13 interviews in the Italian TV or Radio, monthly press releases and 127 articles in magazines and newspapers (see Table 2 for details). Additionally, printed and online educational material was offered to disseminate the project objectives and to help citizen scientists to recognise the target species. This material included: identification guides (available online), posters (950 copies), leaflets (70,000 copies), booklets (15,000 copies), comic-strips (36 available online) and notice boards (35 installed in 10 nature reserves). Continuous contact with the public was maintained by publishing online technical reports and news as well as a bimonthly newsletter. In addition, an incentive was offered to participants for gathering numerous faunistic data: the project website kept tracks of their records, displayed their records on maps, provided their status and offered prizes in connection with the number of records sent.

Volunteer data collection and verification procedures

Two main systems were used to transmit records of the target species: (i) the project website (http://www.lifemipp.eu) and (ii) the app “MIPP” for smartphones and tablets. The system only focused on presence data. The website was developed using the J2EE, Servlet and JSP languages. The mark-up languages were based on HTML5 with JavaScript, LESS and SASS. Apache Tomcat was used as the web server. The first version of the website was online in September 2013 and overall 97 versions of the website were released. The development of the smartphone application started in September 2013. In March 2014, the application for Android was released, whereas the first version for iOS and Windows Phone were released in May 2015. A total of 13 versions for Android, five versions for iOS and five versions for Windows Phone were released. Both the website and the app contained the guide for volunteers and was named “How to report” with step by step instructions. Identification sheets were available for all species and included information on taxonomy, distribution, biology, ecology and conservation status.

To report a sighting, the citizen scientist had to complete an online form (via website or via app) which included mandatory and optional fields. The mandatory fields were: nickname, e-mail address, geographic coordinates (inserted manually or automatically), date and hour of sighting, photograph of the target species and the name of the species observed (although a field named “Unidentified” for uncertain data was also available). The optional fields were: location information, insect position, habitat and additional notes.

Table 1. Number of dissemination activities and number of citizens reached from 2014 to 2016.

	2014		2015		2016		Total	
	Activities	Citizens	Activities	Citizens	Activities	Citizens	Activities	Citizens
Seminars and workshops	25	642	31	2100	26	652	82	3394
Divulgation events	19	715	20	968	18	1539	57	3222
Conferences	5	130	2	140	3	0	10	270
Guided tours	8	257	54	1496	4	170	66	1923
Educational activities at school	58	1923	70	1862	60	1370	188	5155
Total	115	3667	177	6566	111	3731	403	13964

Table 2. Media-related dissemination performed from 2014 to 2016.

	2014	2015	2016	Total
Documentaries	1	1	0	2
Press releases	9	12	13	34
Magazines and newspaper articles	42	37	48	127
Interviews in TV or Radio	4	5	4	13
Total	56	55	65	176

According to the recommendations provided by Lovell et al. (2009), an attempt was made to minimise subjectivity of the volunteers (mandatory photographs, online instructions etc.) and to ensure data quality (validation by experts). Digital photographs were necessary to ensure the validity of the data which was verified and approved by experts who confirmed or rejected the identification. Records without photographs were not accepted with the exception of "expert" citizens (people who had already sent a number of correct records, thereby leading to the acceptance of this source) or, for certain species, whether the records were provided with an accurate description of the insect. Finally, each report submitted acquired an automatic field, i.e. date of reporting.

Once a submission was correctly completed, the system sent a notification to the e-mail address of the citizen scientist who recorded the species and to the specific expert. Based on the data provided, the expert assigned one of five different statuses to the record: (i) confirmed (the species has been correctly identified by the citizen and all the other information provided were plausible), (ii) rejected (the photo showed none of the target species or the other information was implausible), (iii) not publishable (the specimens was part of an entomological collection, the same specimens had been already reported, wrong geographical coordinates, the picture was not clear), (iv) interesting but not target (the picture refers to a species of conservation interest but none of the target species, e.g. *Lucanus tetraodon*) and (v) pending (evaluation in progress). All confirmed reports were displayed on the map of the project website. However, the exact location was not disclosed and the site of the sighting was indicated within a range of 10 km from the original geographic position provided. The exact position was hidden

from the public because the records were considered "sensitive data", due to the species being protected. Volunteers could access the website using their credentials and consult details and exact positions of all the records provided. The reports were stored in the project database. This database is managed through a MySQL relational DBMS (DataBase Management System) and data are exportable as CSV format. At the end of the project, the data will be available and shared with the National Biodiversity Network (http://http://www.naturaitalia.it/banchedati.do) of the Ministry of the Environment.

Statistical analysis of phenology and distribution

Faunistic records were downloaded from the MIPP database on 14.12.2016 and only those records which had been validated by experts were used. The data set contained, amongst other information, the date of the observation and the coordinates. In order to obtain the elevation for each record, two approaches were followed. Firstly, the Google Maps API was used to return elevations for all points, employing the GPS Visualizer (http://http://www.gpsvisualizer.com/geocoder/elevation.html). Secondly, an analysis was performed using the geomorphology tools (DEM) implemented in QGIS (version 2.14.3-Essen). The average of both values was rounded to the nearest metre and these values were used for further analysis. To investigate the altitudinal distribution of the species recorded, the number of records was plotted for six altitudinal ranges (0–400; 401–800; 801–1,200; 1,201–1,600; 1,601–2000 and 2,001–2,400), as this resolution allowed the altitudinal distribution for all target species to be plotted and a statistical analysis comparing different altitudinal ranges for four species to be undertaken. Subsequently, the altitudinal ranges were superimposed on the proportion of the land-surface area of Italy present in the ranges. These were obtained using the processing tools (reclassify) implemented in QGIS (version 2.14.3-Essen).

To investigate the phenology of the target species, two types of analysis were carried out. Firstly, the records for each species were assigned to three 10-day periods in each month and expressed as percentages. The resulting histograms were plotted. In a second step, the change in the phenology with increasing altitude was analysed. To do this, all records of the various species were pooled for the six altitudinal ranges (0–400; 401–800; 801–1,200; 1,201–1,600; 1,601–2000 and 2,001–2,400) and dates were transformed into day of the year (e.g. 1st of January=1). Subsequently for each altitudinal range, a boxplot was created for the pooled days of the year and the median was calculated, defining the day which represented the peak of activity for each altitudinal range. To compare the length of the activity period of the various species at different altitudes, the days were calculated between first and third quartile which define the time when the central 50% of observations were carried out. Phenological data for the different ranges were analysed with the Kruskal-Wallis rank sum test, as implemented in R version 3.1.3 (R Development Core Team 2010). Phenological changes with increasing altitude were only calculated for those species for which the MIPP database held validated data from more than two altitudinal ranges with more than 25 records and only for those ranges with more than 25 records. Thus, these analyses were carried out for *L. cervus*, *M. asper*, *R. alpina* and *P. apollo*.

Results

A total number of 2,308 reports were transmitted to the project database. Most of these reports (n=1,653, 71.6%) were submitted via the website, whereas only 28.4% of the reports (n=655) were submitted via the app (Table 3). The number of annual reports constantly grew from 2014 to 2016 (Table 3). Most of the dates of the sightings fell within the duration of the CS action (2014–2016) and only a small part of records (n=206, 8.9%) were collected prior to 2014 (Table 3). The percentage of records sent via the website decreased between 2014 and 2016 (from 80.6% to 69.2%), while the submission via the app increased (from 19.4% to 37.4%) (Figure 1). To most of the submitted records, the status "confirmed" was assigned by specialists (1,691 out of 2,308 for the whole dataset) (Table 4) and the distribution of these validated records in Italy is presented in Figure 2. The percentages of the five status categories assigned to the reports (confirmed, rejected, not publishable, not target, pending) for records from the years 2014–2016 are given in Figure 3.

The species most commonly recorded was *L. cervus*, followed by *M. asper* and *R. alpina*. The number of discarded and confirmed records was calculated for all nine-target species (Figure 4) and the proportion of confirmed records varied between 87% for *M. asper* and 96% for *L. cervus*, *M. asper*, *R. alpina*, *P. apollo*, *Z. cassandra/polyxena* and *L. achine*. On the contrary, for *C. cerdo*, *O. eremita* and *S. pedo*, only between 44% and 64% of records were confirmed by the experts. The number of sightings per year was calculated for the nine-target species (Figure 5). In general, the number of sightings increased, but some exceptions exist. For example, for *L. cervus,* the number of records from 2014 was higher than from 2015. Similarly, for *C. cerdo* and *P. apollo*, the number of records from 2015 was higher than from 2016. The proportion of records submitted via the app and via the website was calculated for all nine-target species (Figure 6). The app was used to transmit 21% to 31% of records for the five beetle species. In contrast, for butterflies, only 7%–11% of records were transmitted via the app.

A total of 695 citizens submitted at least one record during the three years analysed and the number of participants increased each year (2014: n=182; 2015: n=295; 2016: n=335). Most of the citizens (n=603) transmitted data in only one year, whereas a few provided records during more than one year (n=92). Most of the citizens (n=600) transmitted one to three records, a smaller part of citizens (n=68) submitted

Table 3. Number of records submitted via web, via app and both, for each year and for date of transmission.

Date of transmission	Recorded before 2014			Recorded 2014–2016			All records		
	Web-site	App	Total	Web-site	App	Total	Web-site	App	Total
2014	117	1	118	350	84	434	467	85	552
2015	58	6	64	513	210	723	571	216	787
2016	23	1	24	592	353	945	615	354	969
All reporting date	198	8	206	1455	647	2102	1653	655	2308

Table 4. Number of records submitted via web, via app and both, for the 5 status categories and for date of sightings.

Status category of records	Recorded before 2014			Recorded 2014–2016			All records		
	Web-site	App	Total	Web-site	App	Total	Web-site	App	Total
Confirmed	164	4	168	1169	354	1523	1333	358	1691
Not publishable	6	0	6	7	5	12	13	5	18
Not Target	9	0	9	46	61	107	55	61	116
Rejected	19	4	23	200	207	407	219	211	430
Pending	0	0	0	33	20	53	33	20	53
Tot.	198	8	206	1455	647	2102	1653	655	2308

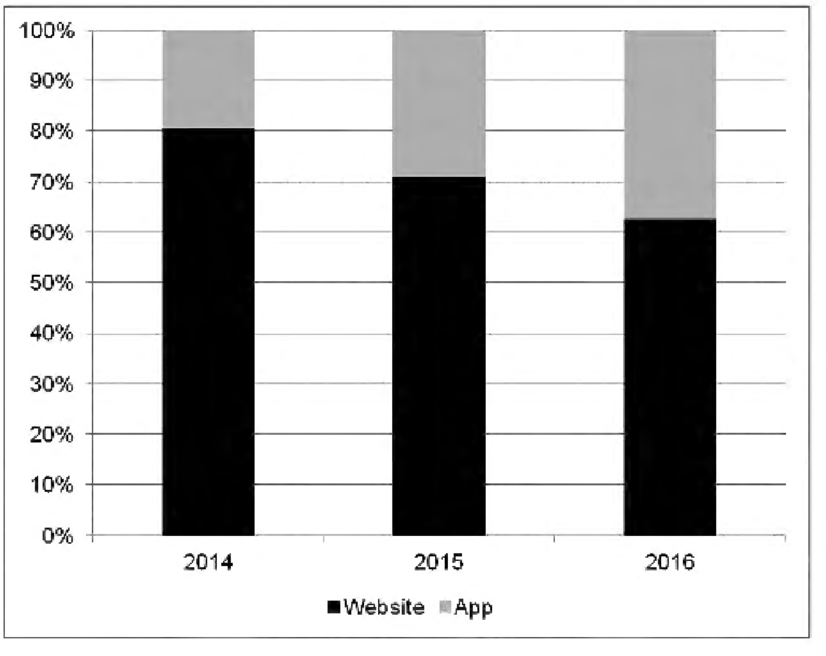

Figure 1. Percentage ratio of reports submitted via web and via app for year (considering the sightings from 2014 to 2016).

Figure 2. Distribution map of confirmed records of the target species collected by citizen scientists during the LIFE MIPP Project.

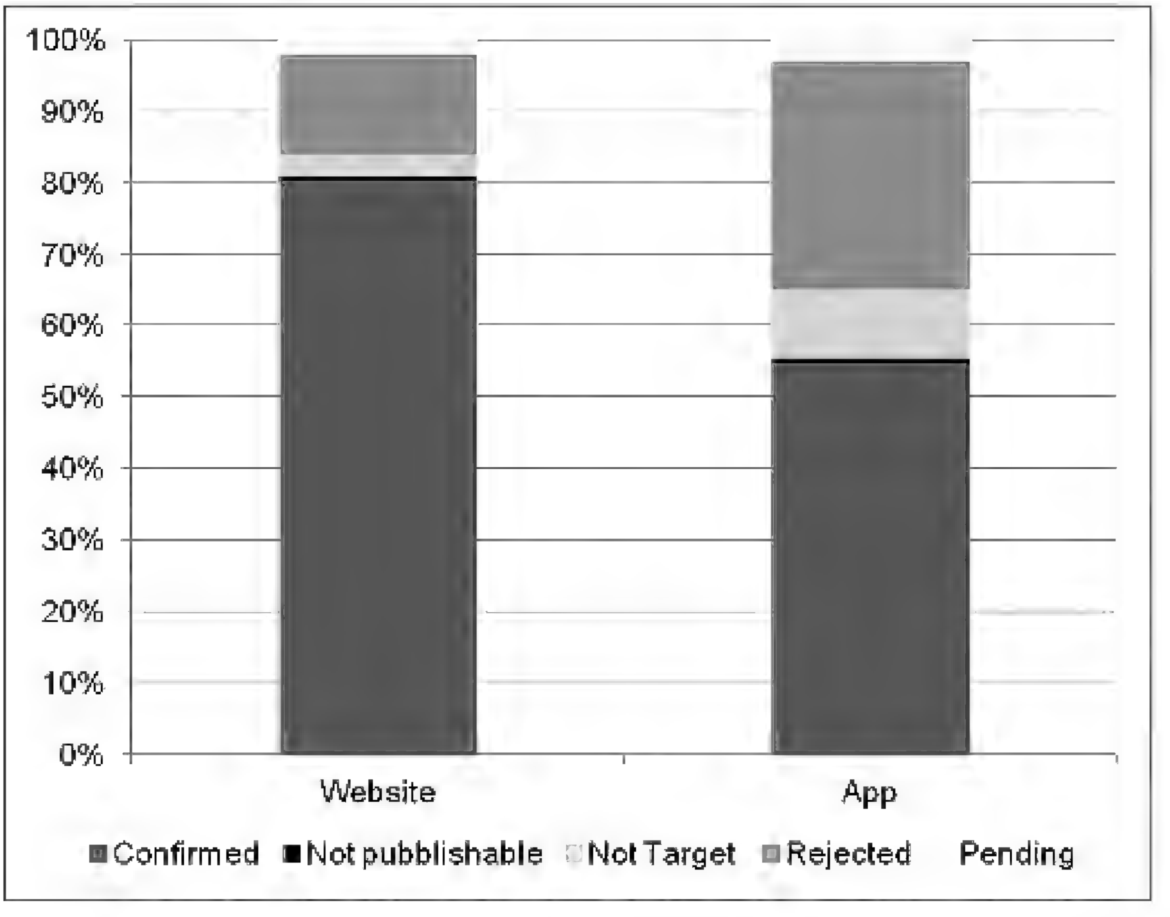

Figure 3. Percentage ratio between the five status categories of the reports (considering sighting date between 2014 and 2016) submitted via web and via app.

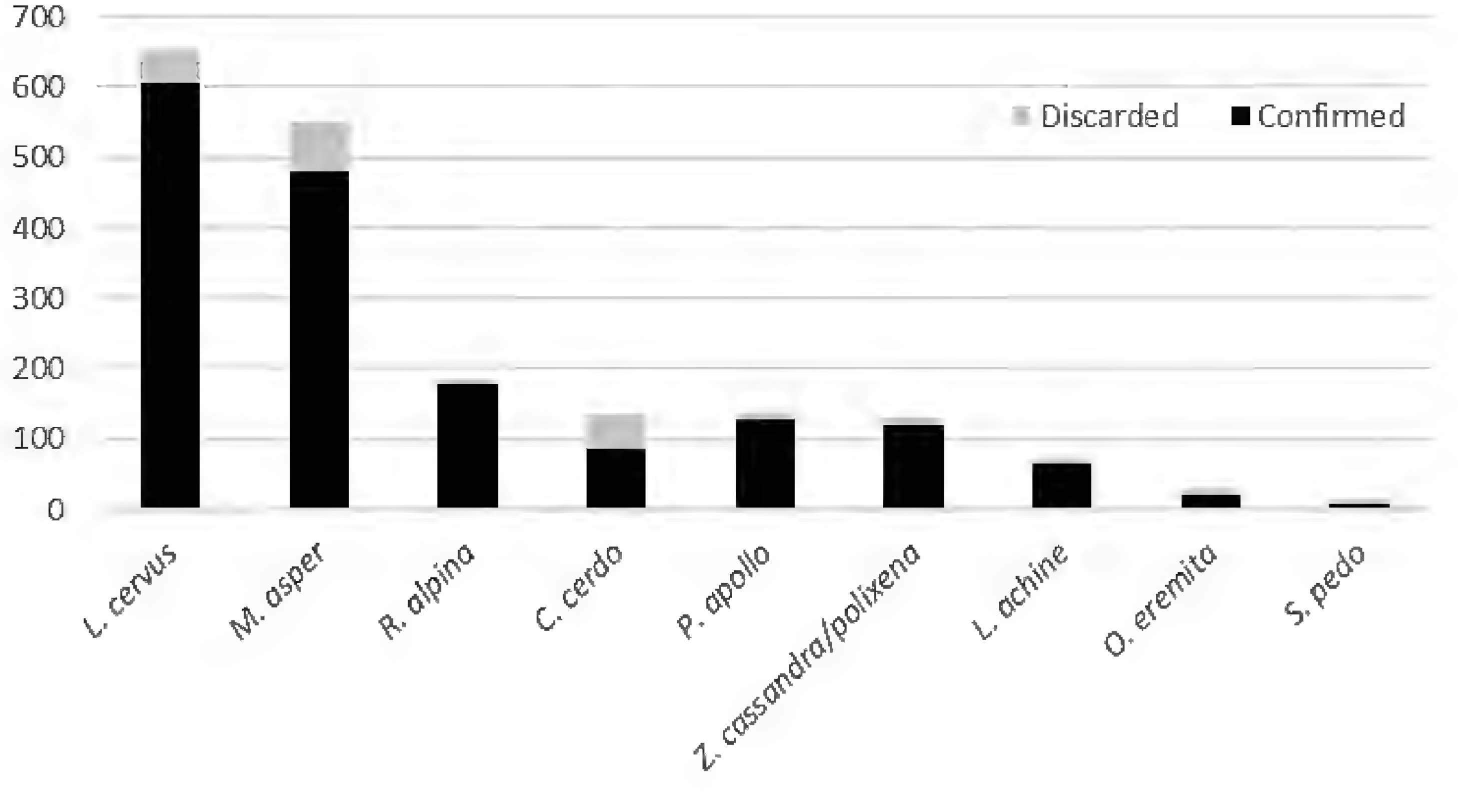

Figure 4. Number of discarded and confirmed records for the nine-target species reported by citizens.

4–10 records each, another group of citizens (n=34) submitted 11–62 records and 1 citizen transmitted 132 records. Figure 7 identifies the number of records in correlation to the number of citizens. Some records without photographs sent by "expert"

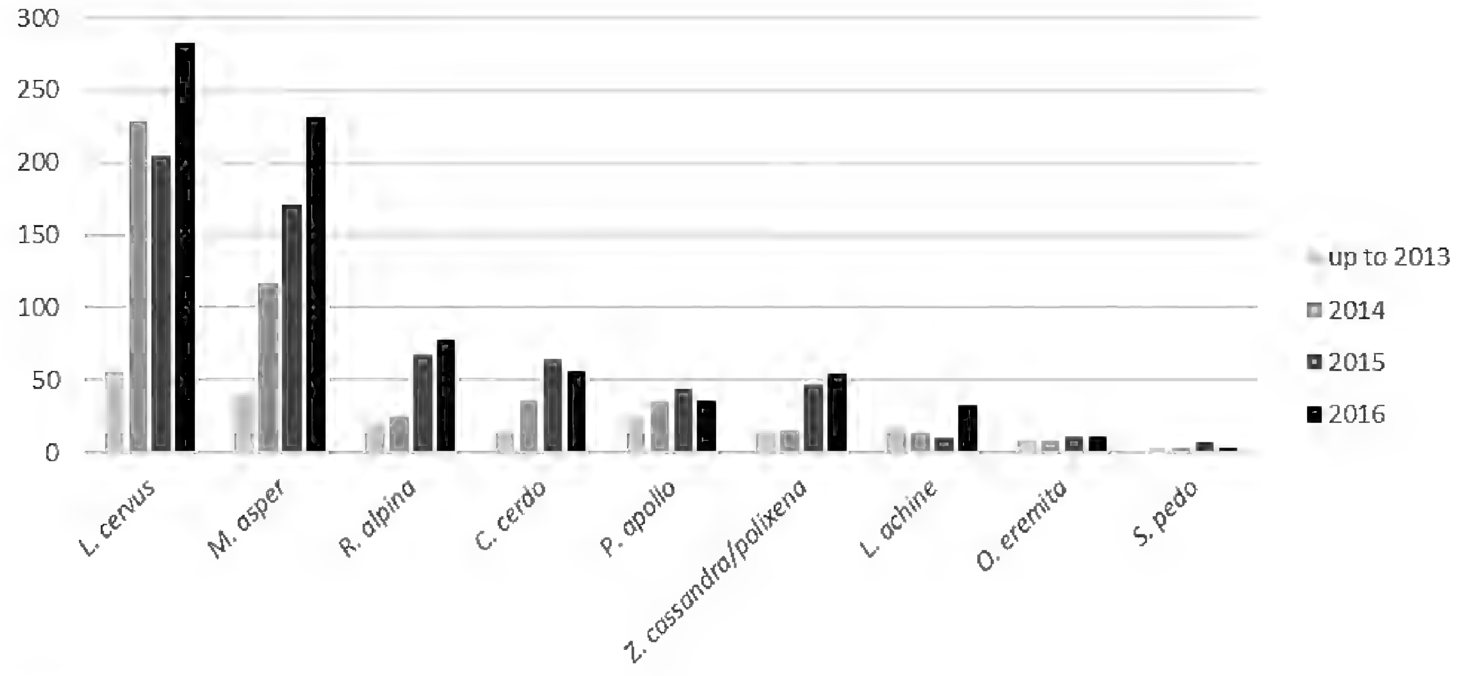

Figure 5. Number of records per year of the nine-target species reported by citizens.

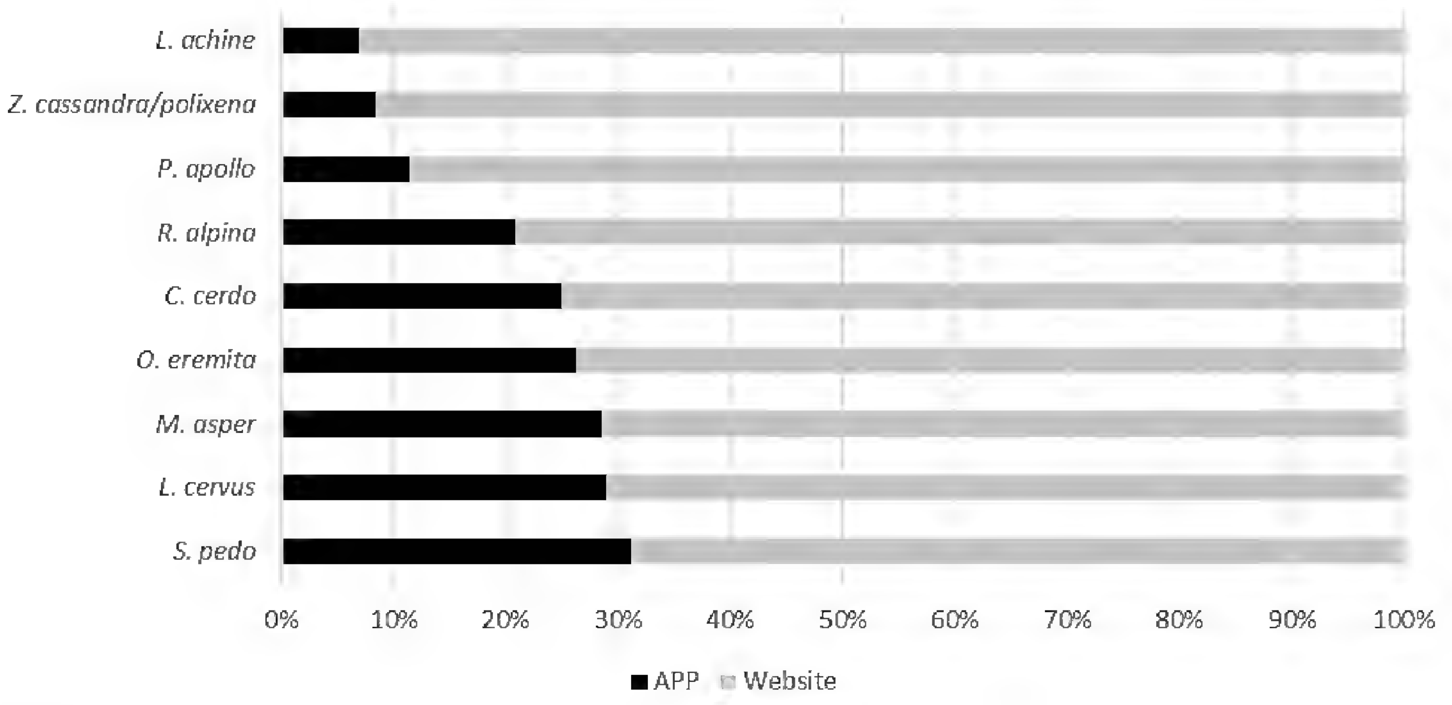

Figure 6. Percentage of records submitted via website and via app for the nine-target species.

citizens (naturalists with a considerable experience in entomology) were accepted, a total of 4.6% of the complete data-set. These mainly concerned *L. cervus* (70 records of 605 records confirmed).

Altitudinal variation

The average difference between the two methods for obtaining altitudes for all points was 8.1 m ±8.8 m standard deviation (SD). The altitudinal distribution of the various species, as revealed by CS data, is presented in Figure 8. These distributions showed

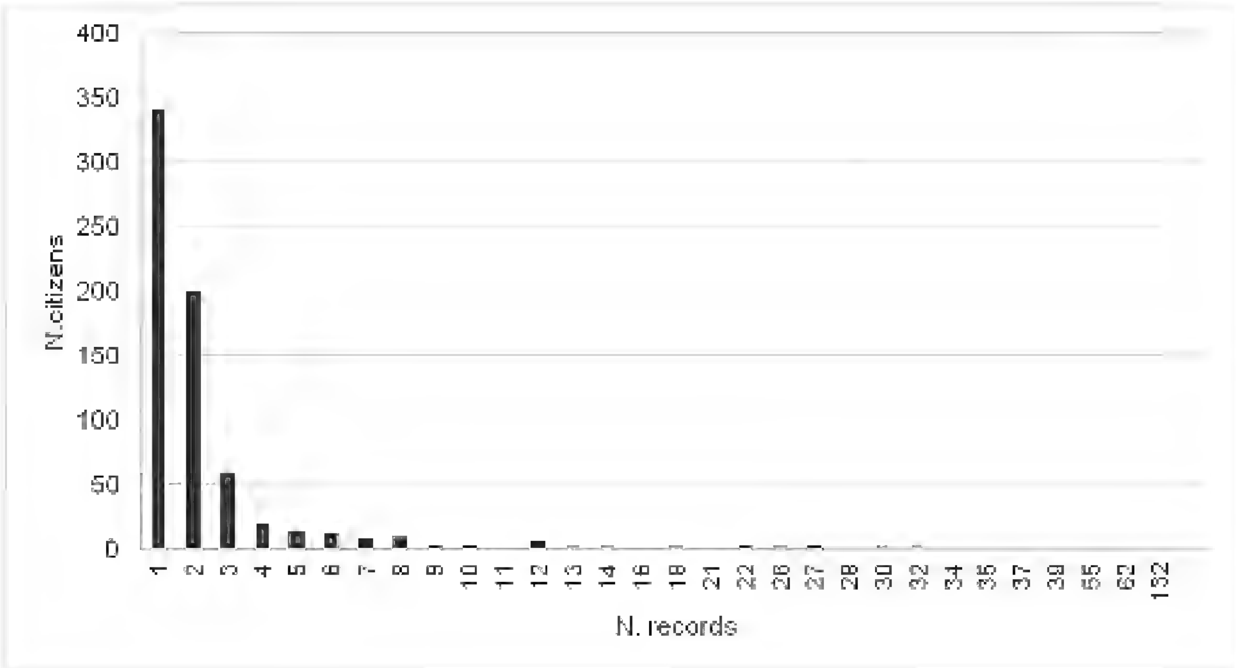

Figure 7. Relationship between the number of provided records and the number of citizens.

distinct patterns for the various species and, for each species, the altitudinal distribution revealed by CS differed substantially from the altitudinal distribution of the Italian territory (Figure 8). For example for *L. cervus*, 67% of observations were carried out in the range 0–400 m a.s.l. but, in Italy, only 18% of the land-surface area are in this altitudinal range. Thus, *L. cervus* was observed more commonly at lower altitudes than would be expected if the species were randomly distributed in the national territory.

The species most commonly recorded at low altitudes was *C. cerdo*, with 79.5% of all observations between 0 and 400 m a.s.l. The lowest record was set at 2 m a.s.l. and the highest at 1,147 m a.s.l. The species with the highest number of observations at high elevations above sea level was *P. apollo*, with 47.6% of all records from the altitudinal range 1,601–2,000 m a.s.l. For this species, the lowest record was from 722 m a.s.l., whereas the highest was from 2,252 m a.s.l. The lowest and highest altitudes for all target species, as revealed by the CS data, are presented in Table 5.

Phenological variation

Phenology for all species is presented in Figure 9. The analysis of phenology in relation to altitude were carried out for *L. cervus*, *M. asper*, *R. alpina*, and *P. apollo* and a total of nine comparisons for different altitudinal ranges were carried out (see below). In all cases, peak activity occurred later with increasing elevation and was on average delayed by 10 days when moving upwards by 400 m a.s.l.

For *O. eremita*, the first observation was from 12 June (2012), while the last observation was from 11 September (2016). Because the histogram (Figure 9) did not

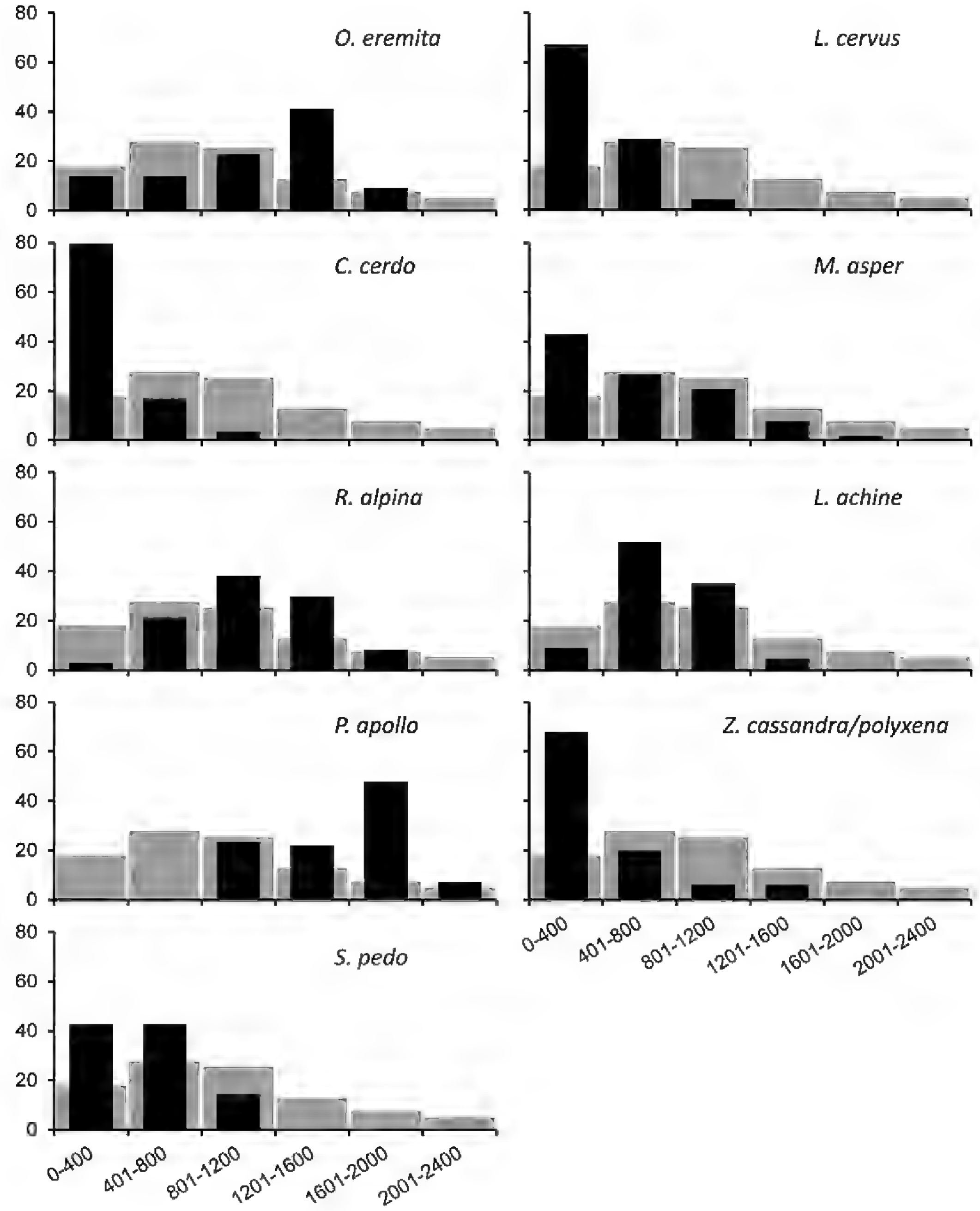

Figure 8. Altitudinal distribution of the target species, as revealed by the citizen science data. The distributions are expressed as percentages of the total number of records and are presented with the altitudinal distribution of the Italian territory as background.

Table 5. The lowest and highest altitude in meters where the target species were recorded according to the citizen science data.

Species	Lowest altitude (m)	Highest altitude (m)
O. eremita	3	1,836
L. cervus	6	1,065
C. cerdo	2	1,147
M. asper	2	1,870
R. alpina	3	1,997
L. achine	179	1,526
P. apollo	722	2,252
Z. cassandra/polyxena	1	1,482
S. pedo	90	860

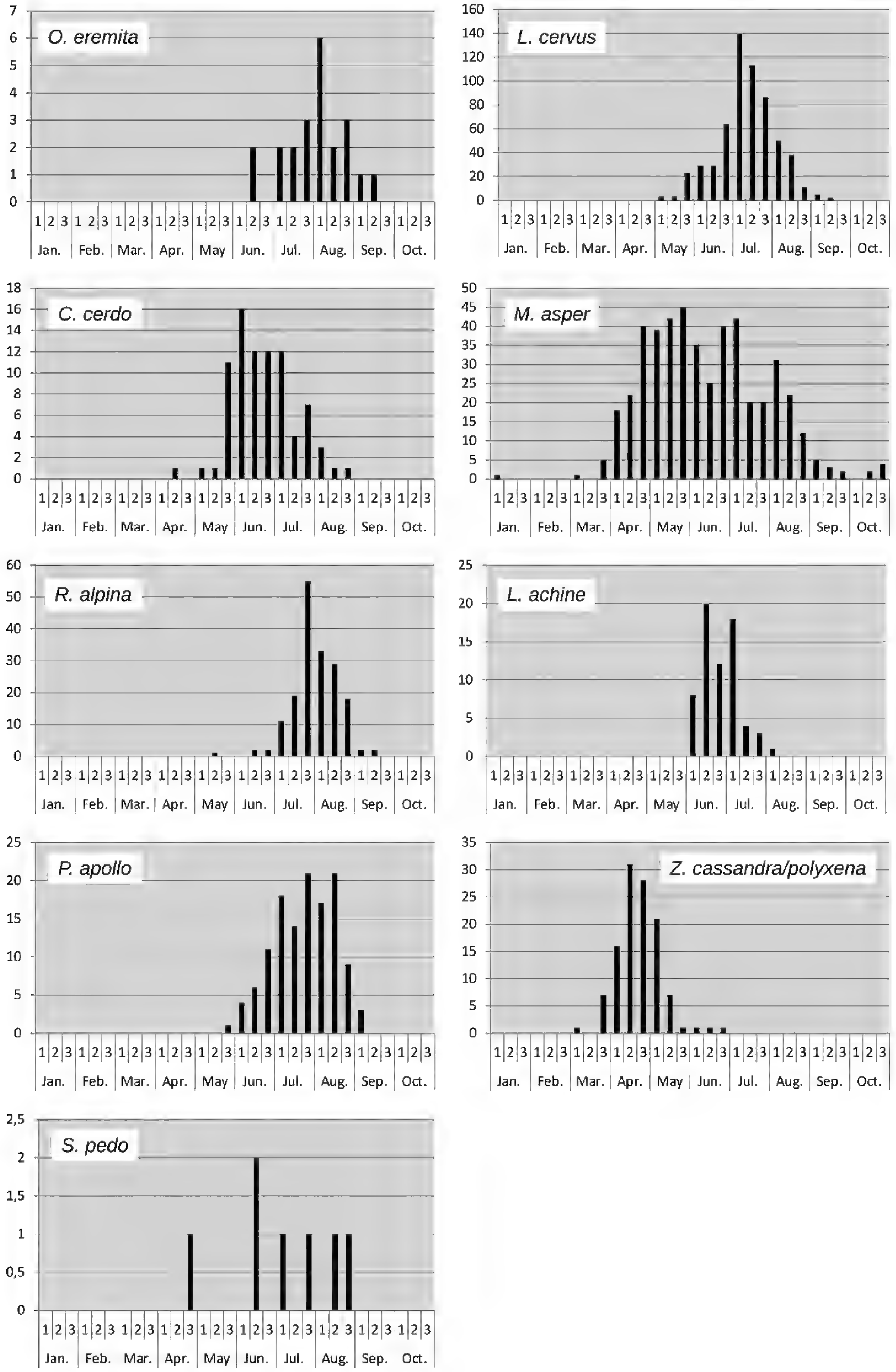

Figure 9. Phenology of the target species, as revealed by the citizen science data.

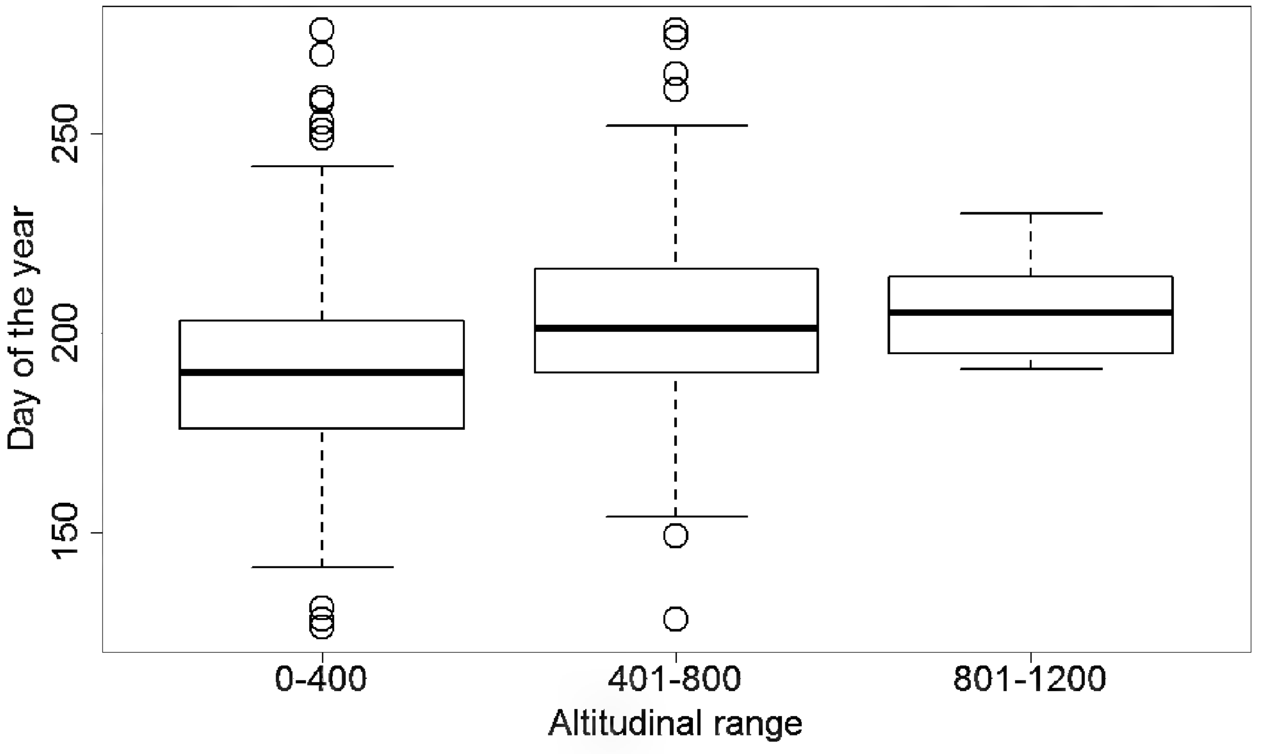

Figure 10. Phenology of *L. cervus* in different altitudinal ranges, based on citizen science data. The boxplots represent the distribution of dates, expressed as "days of the year". The medians for the altitudinal ranges are: 190 (09 July) (0–400 m a.s.l.); 201 (20 July) (401–800 m a.s.l.); 205 (24 July) (801–1,200 m a.s.l.).

show a clear pattern, the central 50% of observations were calculated for *O. eremita*. This analysis showed that the main activity period was between 19 July and 18 August.

The earliest record of *L. cervus* was from 06 May (2015) and the latest from 17 September (2016) while high numbers were observed between the end of June and early August. For this analysis, remains recorded in September and October were not considered, as old remains can be found weeks after the end of the flight period (Campanaro et al. 2011). The phenology of *L. cervus* changed with increasing altitude (Figure 10) and this was highly significant (χ^2 = 167.3, df = 108, p < 0.001). Peak of activity was observed on 09 July for the altitudinal range 0–400 m a.s.l., but 20 July at 401–800 m a.s.l. At higher elevations (801–1,200 m a.s.l.) the peak of activity was observed on 24 July. In addition, the length of the activity period varied considerably for the different altitudinal ranges. Whereas the central 50% of observations were made in 27 days at 0–400 m a.s.l. and in 26 days at 401–800 m a.s.l., the same percentage was observed at the highest altitude investigated (801–1,200 m a.s.l.) in only 19 days.

The earliest record of *C. cerdo* was on18 April (2013) and the latest on 30 August (2016), while high numbers of this beetle were observed between late May and early July. For *M. asper*, the earliest record was on 08 January (2015) and the last one on 29 October (2016). Large numbers of this longhorn beetle were observed for an extended period, which lasted from mid-April to mid-August. As in *L. cervus*, phenological changes between the different altitudinal ranges were marked. The peak of activity for *M. asper* was observed even later in the year as altitude increased (Figure 11) and this trend was highly significant (χ^2 = 209.2, DF = 157, p = 0.003). Whereas the peak of activity was observed at low altitudes (0–400 m a.s.l.) on 23 May, this date was even

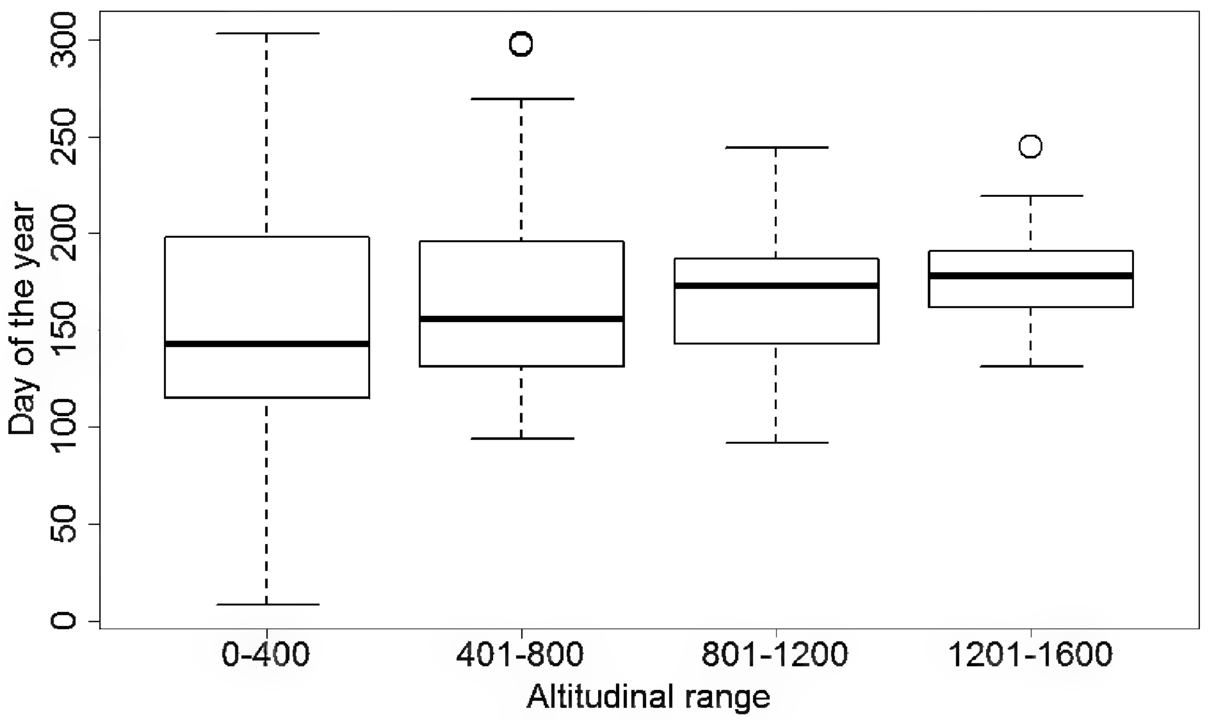

Figure 11. Phenology of *M. asper* at different altitudinal ranges, based on citizen science data. The box-plots represent the distribution of dates, expressed as "days of the year". The medians for the altitudinal ranges are: 143 (23 May) (0–400 m a.s.l.); 156 (05 June) (401–800 m a.s.l.); 173 (22 June) (801–1,200 m a.s.l.); 178 (27 June) (1,201–1,600 m a.s.l.).

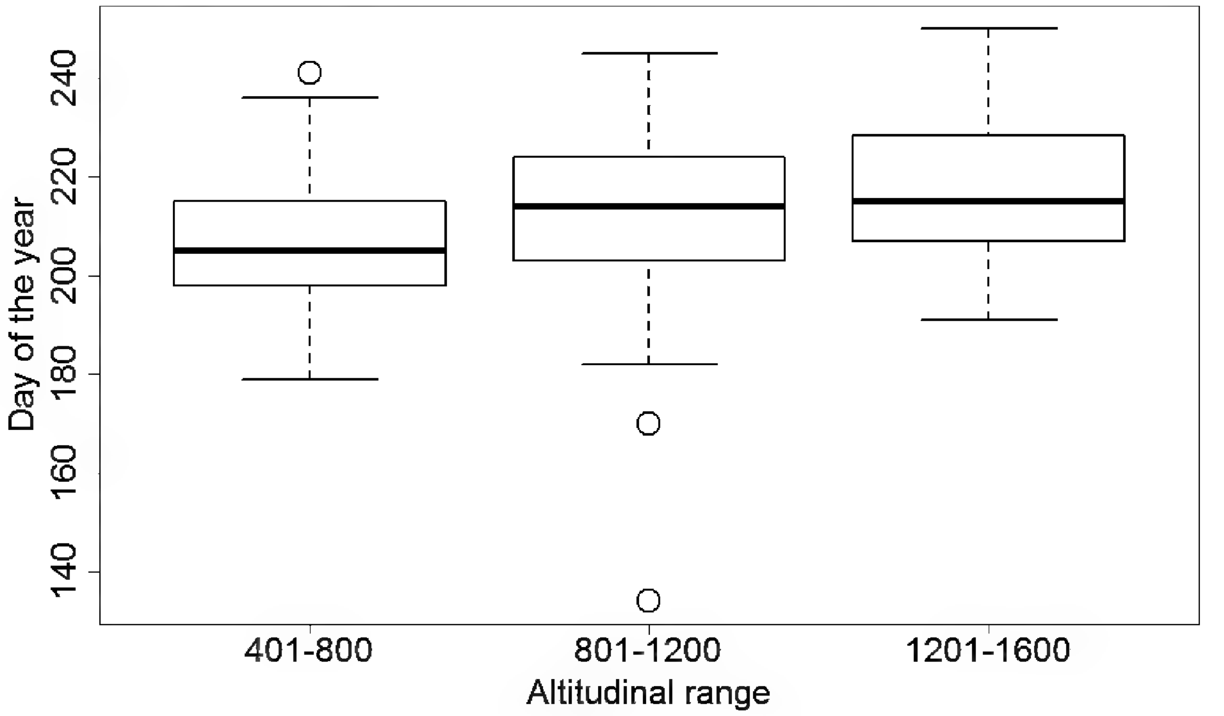

Figure 12. Phenology of *R. alpina* in different altitudinal ranges, based on citizen science data. The box-plots represent the distribution of dates, expressed as "days of the year". The medians for the altitudinal ranges are: 205 (24 July) (401–800 m a.s.l.); 214 (02 August) (801–1,200 m a.s.l.); 215 (03 August) (1,201–1,600 m a.s.l.).

later in the year with increasing elevations. At 401–800 m a.s.l., the peak of activity was observed on 05 June and at 801–1,200 m a.s.l. on 22 June. At 1,201–1,600 m a.s.l., the median fell on 27 June. Again, the length of the activity period decreased with in-

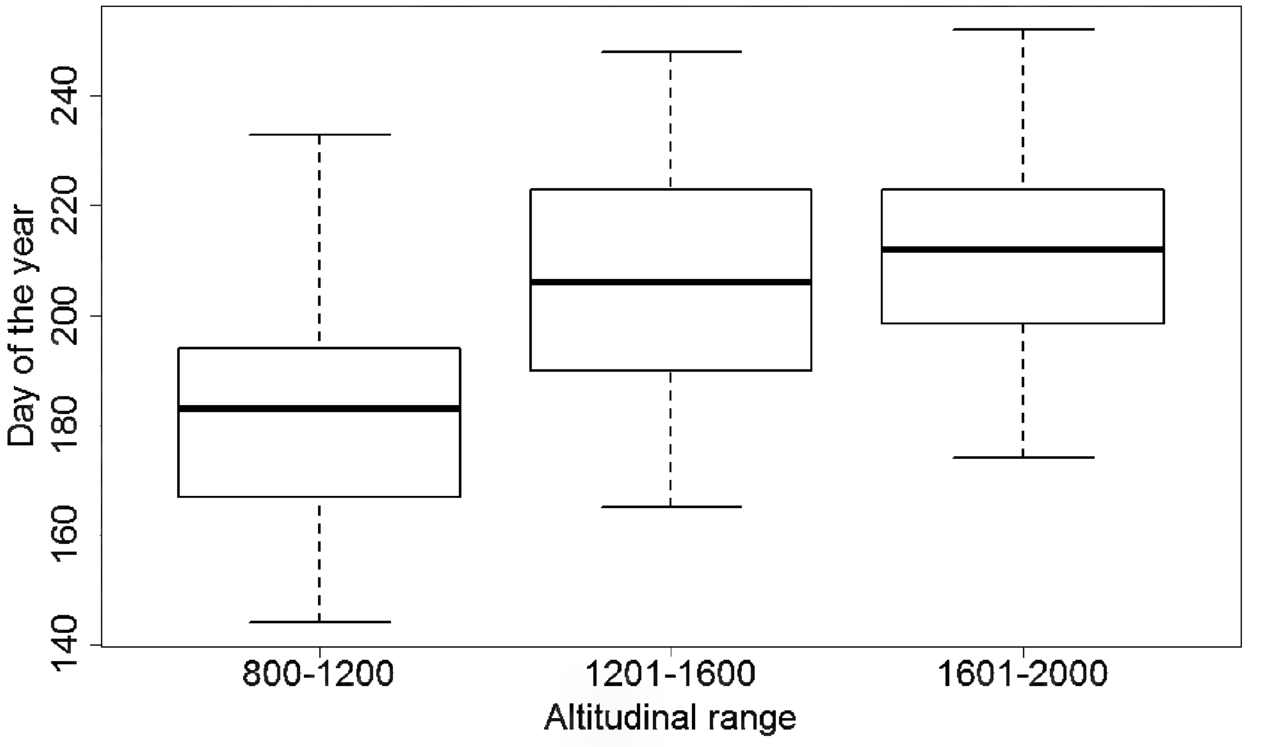

Figure 13. Phenology of *P. apollo* in different altitudinal ranges, based on citizen science data. The box-plots represent the distribution of dates, expressed as "days of the year". The medians for the altitudinal ranges are: 183 (02 July) (800–1,200 m a.s.l.); 206 (25 July) (1,201–1,600 m a.s.l.); 212 (31 July) (1,601–2,000 m a.s.l.)

creasing elevation. Whereas the central 50% of observations of *M. asper* were made in 83 days at 0–400 m a.s.l., the same percentage of data was collected in only 65 days at 401–800 m a.s.l. and in 44 days at 801–1,200 m a.s.l. While at 1,201–1,600 m a.s.l., 50% of observations were collected in only 29 days.

For *R. alpina*, the earliest record was on 13 May (2016) and the last one on 17 September (2015). A large number of this longhorn beetle was observed from early July to late August. In this species, phenological changes between the different altitudinal ranges were also marked (Figure 12), but these were not statistically significant ($\chi^2 = 51.7$, DF = 58, $p = 0.706$). Whereas the peak of activity was observed at the altitudinal range 401–800 m a.s.l. on 24 July, this date was observed at 801–1,200 m a.s.l. on 02 August. At 1,201–1,600 m a.s.l., the peak of activity fell on 03 August. The length of the activity period did not show a clear pattern in correlation with elevation. The central 50% of observations of *R. alpina* were made in 17 days at 401–800 m a.s.l., the same percentage of data being collected in 21 days at 801–1,200 m a.s.l. as well as at 1,201–1,600 m a.s.l.

L. achine was observed between 02 June (2011) and 01 August (2013), with most observations from mid-June to early July.

The earliest record of *P. apollo* was on 24 May (2015) and the latest on 09 September (2014), while high numbers were observed between early July and mid-August. The phenology of *P. apollo* changed with increasing altitude (Figure 13) but this trend was not significant ($\chi^2 = 68.5$, DF = 58, $p < 0.162$). The peak of activity was observed on 02 July for the altitudinal range 800–1,200 m a.s.l., but at 1,201–1,600 m a.s.l. this occurred later, on 25 July. At even higher elevations (1,601–2,000 m a.s.l.), peak activity was observed on 31 July. The length of the activity varied between the different altitudinal ranges, but

not in a consistent manner. Whereas, the central 50% of observations were made in 27 days at 800–1,200 m a.s.l. and in 33 days at 1,201–1,600 m a.s.l., the same percentage was observed at the highest altitude investigated (1,601–2,000 m a.s.l.) in 25 days.

For *S.pedo,* the number of records was too small (n=7) to allow for any meaningful analysis of the phenology. For *Z. cassandra* and *Z. polyxena*, the earliest record was on 09 March (2016) and the latest on 30 June (2014), while high numbers were observed exclusively between early April and early May.

Discussion

The present study represents the first application in Italy of the CS approach to the study of insect species listed in the Habitats Directive; it is also the first time that the CS approach has been applied to rare and/or elusive insect species (i.e. *R. alpina*, *O. eremita*, *S. pedo*, *L. achine*).

The CS programme presented in this paper can be considered successful in terms of citizen response, records transmitted, scientific outputs and social outcomes. The number of records provided is high considering the ecology and biology of the target species which are rare, have a localised distribution and have a restricted activity period. The response by citizens followed a positive trend, both considering the number of records provided and the number of citizens involved, thus demonstrating that the interest in the project was maintained over more than one year. The continuous contacts with volunteers (guaranteed by e-mails), the high number of public events and the different dissemination tools, certainly contributed to this result, because "identity and motivation are crucial to maintaining committed volunteers" (Kobori et al. 2016).

The preferred method for transmitting records was the website, even if the percentage of data sent via the app was increasing. One possible reason for this prevalence for using the website could be that photographs of reasonable quality of the target species were easier to take with cameras and a macro lens. The inbuilt cameras of smartphones were less suitable for this purpose. However, the increasing use of the app MIPP over the years might be due to several factors, amongst them being: advances in the usability of the app, better internet connections, better promotion for the app, or more simply, citizens who send records are middle-aged people (average age 44) and increasingly use smartphones and apps.

The high rate of correct validations (73%) confirmed that the majority of the data collected by volunteers were correct. Similarly, Gardiner et al. (2012) found that citizen scientists correctly identified lady beetles in 81–100% of cases. Ratnieks et al. (2016) reported that volunteers correctly identified between 79% and 94% of insects and they showed that the type of training method had a significant effect on identification accuracy. Thus, the ability of citizens in recognising the target species suggested that the information provided to facilitate species identification during the MIPP project was useful or that they had personal expertise in entomology. However, these data,

which contained 27% of erroneous records, also showed that validation was a crucial step in a CS project to ensure the scientific quality of the data collected by citizens (cfr. Delaney et al. 2008, Zapponi et al. 2017).

L. cervus was the most frequently recorded species, probably due to the fact that it is a relatively large and common species in northern and central Italy. The high number of records for *R. alpina* was surprising as this species has a fragmented distribution in Italy and is restricted to a very specific habitat (open beech forests). However this species is stunning and recognizable due to its typical colour pattern: the body is velvet blue-gray with black spots. It might also be that this species is becoming more common, as has been observed in Switzerland (Lachat et al. 2013).

The analysis of the participation of citizens in terms of the number of records provided, showed that a small share of participants contributed with many data and many contributed with few data. In other words, a large group of citizens occasionally contributed to the project (providing one to three records) and a small group of citizens contributed constantly (providing dozens of records). This pattern was also reported by Boakes et al. (2016), who examined the composition of three CS datasets and found that most volunteers contributed few records and were active for just one day. Furthermore Boakes et al. (2016) emphasised that the main objective is to encourage citizens to further their skills in the research of the target species and to provide support for new volunteers. An example of the importance of the CS initiative was reported by Zapponi et al. (2017). Using a subset of the dataset analysed here (2 years, 3 species), the authors demonstrated the high value of this CS initiative, as the quality of occurrence data gathered by volunteers was similar to the data collected exclusively by experts. In addition, Widenfalk et al. (2014) emphasised that data collected by citizens represent an extremely valuable instrument for studies on ecology and distribution. It is believed that CS can not only provide collections of valid data, but also represents a positive way to connect people with nature and this can increase the collective knowledge on conservation values and threats for the environment (Devictor et al. 2010).

Phenological and altitudinal variation

The records collected with the CS approach, allowed detailed analysis of altitudinal distribution and phenology of the target species, particularly for those with the highest numbers of records. Additionally, Polgar et al. (2013) stated that, for insect phenology studies, reliable CS data can be a powerful tool for scientific analysis.

The comparison between traditional biological recording schemes and CS approaches to gather data on species distributions was examined by van der Wall et al. (2015). The two recording approaches revealed similar abundances of bumblebee species but different geographical distributions. CS records displayed more extensive geographic coverage, reflecting human population density, thus offering better opportunities to account for recording effort (van der Wall et al. 2015).

The analysis performed on records collected by citizens showed that the patterns of altitudinal distributions for all species differed from that of the Italian land-surface. This means that the species were not observed randomly, but records followed species-specific altitudinal distributions. These patterns might be influenced by different frequencies of visits of citizens to the various altitudes, but these data do not permit this investigation. The abundant data for *L. cervus*, *M. asper*, *R. alpina* and *P. apollo* also permitted the species phenology to be investigated for specific altitudinal ranges and led to the statement that their peak of activity was delayed by 10 days on average for populations recorded with an increase in altitude of 400 m. To the best of the authors' knowledge, such detailed phenological information has not been available prior to this study. In the following paragraphs, the results obtained from the CS data are compared with the information available in literature for all species investigated.

The citizen scientists reported *O. eremita* at altitudes between 3 m and 1,836 m a.s.l. This upper limit is higher than that reported for Italy by scientific literature (Ranius et al. 2005), who stated that the species has been recorded up to 1,500 m a.s.l., similar to the altitudinal ranges reported for Bosnia-Herzegovina (50–1,350 m a.s.l.) and Greece (100–1,200 m a.s.l.) (Tauzin 1994, Ranius et al. 2005). However, one population of the *O. eremita* complex was recently recorded in Calabria (southern Italy) at 2,000 m a.s.l. (Mazzei A. and Brandmayr P. pers. com.). For *O. eremita*, the volunteers recorded it between 12 June and 11 September. These data are in accordance with those of Bologna et al. (2016a) reported for Italy. Whereas, Schaffrath (2003) reported for Germany that adults are active from June to early August and Ranius et al. (2005) stated for Europe in general, that the adults of *O. eremita* are normally found from July to September. However, in some European regions (Germany, Slovenia and Italy), there have been several observations in June and even single findings in April and May (Ranius et al. 2005).

The altitudinal data derived by the records for *L. cervus*, ranged from 6 m to 1,065 m a.s.l., with more than 65% of the observations from sites below 400 m a.s.l. This altitudinal range is very similar to that given by Campanaro et al. (2011) i.e. from sea level up to 1,000 m a.s.l. Across Europe, the altitude at which the beetle lives varies from 5 m to 1,700 m a.s.l. in Bulgaria (Harvey et al. 2011). However, the species is generally reported as abundant below 200 m a.s.l. and, in northern Spain, does not occur above 800 m a.s.l. (Alvarez Laó and Alvarez Laó 1995). *L. cervus* was observed by citizen scientists between 06 May and 17 September. This period is more extended than most other studies; the only exception being Vrezec (2008), who also analysed non-systematically collected data and reported observations for this species from 19 March to 19 September. However, phenological data are generally based on monitoring and report shorter periods of time for the activity of the species. For example, Campanaro et al. (2016) reported sightings from the end of May to the end of August and similarly Harvey et al. (2011) gave the following dates: 24 May to 05 August, Sprecher Übersax and Dürrer (1998) in Switzerland observed *L. cervus* between 25 May and 04 July. The volunteers reported high numbers of records between the end of June and early August, with a clear peak in early July. Most authors agree that high numbers of adults of this species can be observed between mid June and the end of July (e.g., Vrezec 2008, Chiari

et al. 2014, Campanaro et al. 2016, Scaccini and Anaclerio 2016, Bardiani et al. 2017, Tini et al. 2017) and a peak of activity is in late June or early July (Campanaro et al. 2016). The CS results confirmed the phenology obtained from the ecological studies in Italy (Chiari et al. 2014, Bardiani et al. 2017, Tini et al. 2017) and showed a close correlation between phenology and altitude. In fact, at increasing altitudes, the length of the activity period decreased, whereas the peak of activity shifted forward.

Although *C. cerdo* was recorded between 2 m and 1,147 m a.s.l. by the CS approach, approximately 80% of all observations were made between 0 and 400 m a.s.l. This altitudinal range is similar to that reported for France, where the species was found below the altitude of 900 m a.s.l. (Horák et al. 2010). The data collected by volunteers for the MIPP project showed that *C. cerdo* was active from 18 April to 30 August, while high numbers of this beetle were observed between late May and early July. In the Iberian Peninsula adults are active from early May to late August, but in southeastern Spain, where average temperatures are higher, adult activity spans from February to June (Peris-Felipo et al. 2011). In France, adults are active from June to September (Bensetti and Gaudillat 2002).

Based on data recorded by citizens, the longhorn species *M. asper* was recorded between 2 m and 1,870 m a.s.l. This altitudinal range is in agreement with data reported by Anonymous (2015) and Bologna et al. (2016b), whereas other authors indicated the upper distributional elevation to be lower (Romero-Samper and Bahillo 1993, Bringmann 1996, Vrezec et al. 2009). The data collected by volunteers for the MIPP project showed that *M. asper* was active for most of the year, from 08 January to 29 October. This long period, which covers more than 10 months, is much longer than the activity periods reported generally in literature (López-Vaamonde et al. 1993, Romero-Samper and Bahillo 1993, Bringmann 1996, Drovenik and Pirnat 2003, Polak 2012, Bărbuceanu et al. 2015). Vrezec (2008), who also analysed data collected non-systematically, found that *M. asper* was active for a similar length of time: from 02 February to 30 September. The long activity period observed with the CS approach is in line with the observation that adults of *M. asper* can overwinter (Polak 2012, Rossi de Gasperis et al. 2016). The finding that the peak of activity was observed even later during the year with increasing altitude, while the length of the activity period decreased with increasing altitude, is in keeping with ecological theory but, to the authors' knowledge, no comparable data have been published for *M. asper*. These dates give important indications when planning monitoring fieldwork. However, it is important to note that, at Bosco Fontana (25 m a.s.l.), in the Po river plain of Italy, the peak of activity was observed even earlier during the monitoring activities carried out during the MIPP project, with a peak observed from mid to late April (Hardersen et al. 2017, unpubl. data). In contrast, the CS data indicated the peak of activity on 23 May at an altitude of 0–400 m a.s.l.

The observations of *R. alpina* were reported by volunteers from 3 m to 1,997 m a.s.l. These elevations are very similar to those stated by Lachat et al. (2013) for Europe, where the species is spread from the sea coast to about 2,000 m a.s.l. Other authors reported the upper limit for *R. alpina* to be lower. For example, Bologna et al. (2016c) reported that this species is present from sea level to 1,500 m a.s.l. Similarly,

for Switzerland, Duelli and Wermelinger (2005) reported the species for an altitude up to 1,500 m a.s.l. The CS records are from 13 May to 17 September, with large numbers of observations from early July to late August. These dates are very similar to those provided by Vrezec (2008) for Slovenia, which are also based on data non-systematically collected. Here, *R. alpina* was observed between 04 May and 22 September and 50% of observations were concentrated between 14 July and 08 August. This analysis also showed that, for *R. alpina*, the peak of activity was observed later at higher altitudes.

The butterfly *L. achine* was observed between 02 June and 01 August, with most observations from mid-June to early July. This phenology is similar to that reported for the region Veneto (Italy), where the species was most frequently observed between mid-May and early July (Bonato et al. 2014). The volunteers reported observations at altitudes ranging from 179 m to 1,526 m a.s.l., a range similar to that reported for the Veneto region (300–1,430 m a.s.l.) (Bonato et al. 2014) and for the rest of the Italian Alps, where the species has been recorded up to approximately 1,600 m a.s.l. (Villa et al. 2009). Tolman and Lewington 2008 also reported a similar altitudinal range (200–1,500 m a.s.l.).

Volunteers reported sightings of *P. apollo* from 722 m to 2,252 m a.s.l. and this altitudinal range is similar to that reported for Italy (600–2,300 m a.s.l.) (Villa et al. 2009) and in general (500–2,400 m a.s.l.) (Tolman and Lewington 2008). In contrast, the observations for the Veneto region are at slighter lower elevations, from 400 m to 2,000 m a.s.l. (Bonato et al. 2014). The butterfly *P. apollo* was observed from 24 May to 09 September, but high number of observations were madefrom early July to mid-August. This phenology is very similar to that reported for the Veneto region, where adults have been observed from 13 May to 10 September, with a peak in the second half of July (Bonato et al. 2014). The phenology of *P. apollo* changed with increasing altitude and the peak of activity was delayed as altitude increased. The authors are not aware that this trend has been reported before.

The two butterflies *Z. cassandra* and *Z. polyxena* were observed by volunteers between 1 m and 1,482 m a.s.l., with 68% of observations below 400 m a.s.l. These data are in line with observations from the Veneto region, where the species has been recorded from the plains to 1,200 m a.s.l. (Bonato et al. 2014). On the contrary, Tolman and Lewington (2008) reported the occurrence of this species from 0–1,700 m a.s.l., but generally below 900 m a.s.l. In contrast, Villa et al (2009) reported for Italy that the species is present up to approximately 1,000 m a.s.l. For both butterflies, the earliest record was from 09 March (2016) and the latest from 30 June (2014), while high numbers were observed exclusively between early April and early May.

S. pedo was observed by volunteers between 90 m and 860 m a.s.l., but the small number of records (n = 7) did not permit any meaningful analysis.

In all investigated cases, the peak of activity was observed later with increasing altitude and it was delayed by 10 days on average when moving upwards by 400 m. Additionally, for the two cases where the CS MIPP project provided a large dataset (*L. cervus*, *M. asper*), with 604 and 476 records respectively, the length of the activity period decreased with increasing altitude. These indications are important for the

monitoring protocols, as they give some indications for the timing and duration of the monitoring periods at different altitudes (Bardiani et al. 2017, Hardersen et al. 2017).

Generally, the data collected non-systematically by volunteers allowed altitudinal distribution and phenology to be analysed, at least for those species for which a minimum number of records had been collected. Similarly, Zapponi et al. (2017) showed that CS projects can provide reliable distributional data for poorly known species of high conservation priority and previously, Vrezec (2008) had successfully used non-systematically collected data to infer the phenology of saproxylic beetles. Additionally, Schmeller et al. (2009) reported that volunteer-based schemes can yield unbiased results for the status of species. However, creating and maintaining a large-scale CS network is a multi-year, tiered process, requiring a great deal of investment in order to enable it to flourish, expand and remain sustainable (Delaney et al. 2008).

Altogether, our results confirm that the CS approach, if based on an adequate effort of dissemination, is a reliable tool for gathering or implementing information on distribution and phenology of rare and protected species for which an extensive knowledge referred to a wide territory (e.g. national scale) can be lacking or incomplete. The main advantage of our CS approach is that data-collection does not start from preconceived assumptions and thus provides data from sites and/or dates from which entomologists would not have expected the occurrence of the species.

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